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# **“Large Scale PEM Electrolysis to Enable Renewable Hydrogen Fuel Production”**

## **Alternative Energy NOW** **2/10/10**

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# Presentation Outline

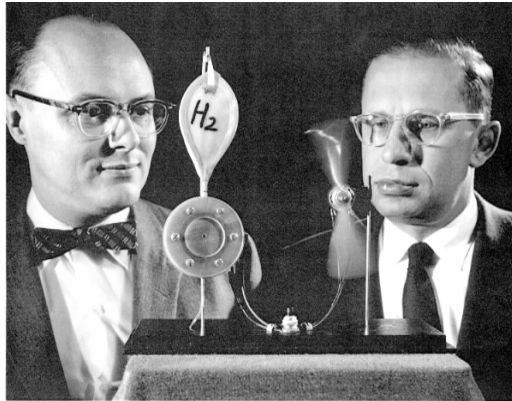
- Company overview
- Introduction to PEM electrolysis
- Development program overview and results
- New product platform launch

# Proton Energy Systems

- World leader in PEM electrolysis
- Founded in 1996
- Located in Wallingford, Connecticut.
- ISO 9001:2000 registered
- Over 1,200 systems operating in 58 different countries.

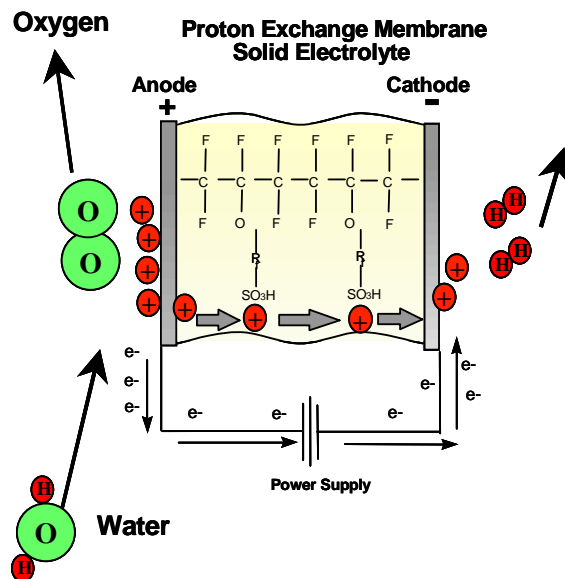


# Development of PEM Electrolysis

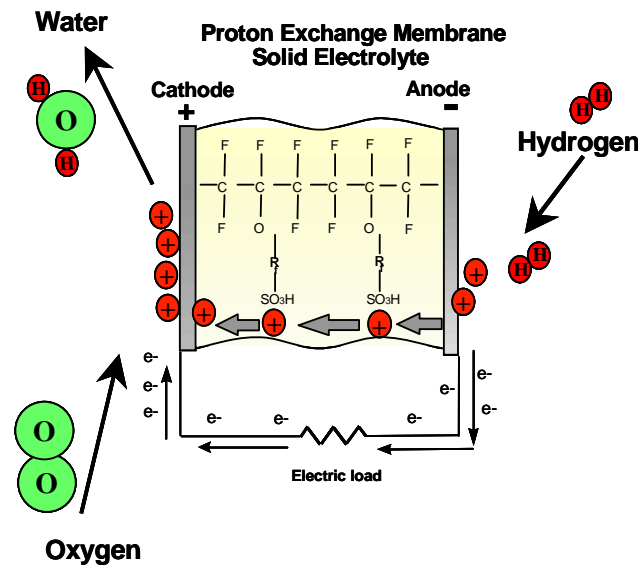


*Initial PEM innovators  
Grubb & Neidrach,  
GE Research, 1955*

**PEM Electrolysis**

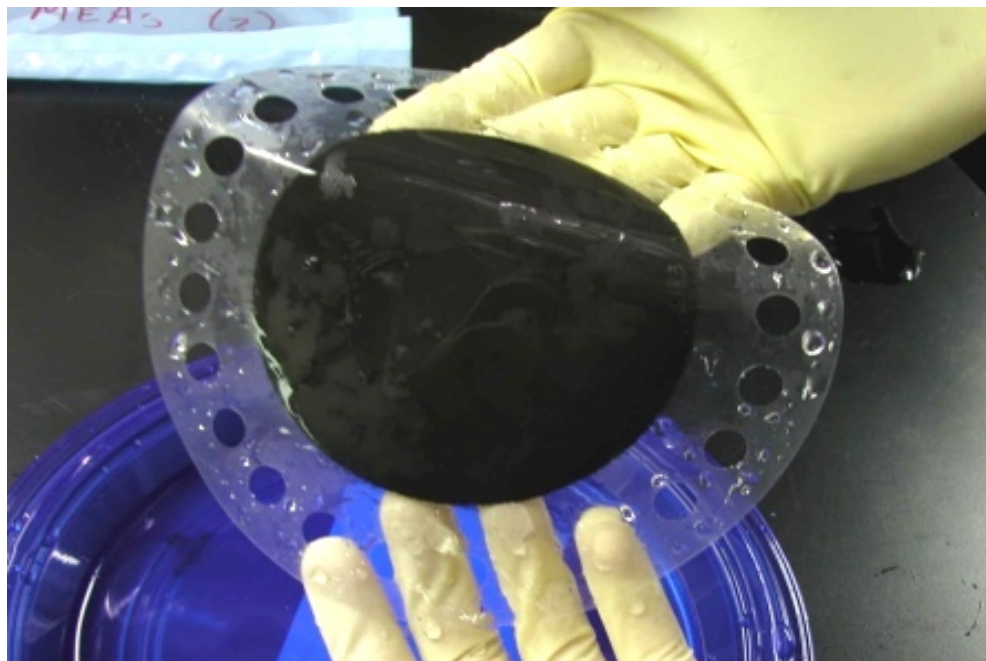


**PEM Fuel Cell**



## PEM (Proton Exchange Membrane)

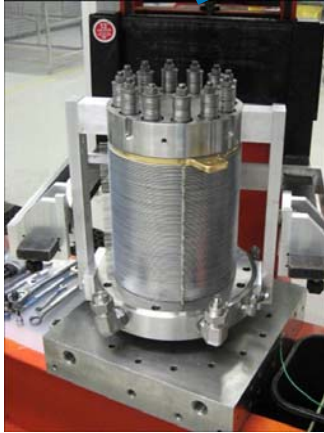
...is at the heart of Proton's hydrogen generation technology





# PEM Electrolyzer technology has a long history of reliability in critical military applications:

## SSN and SSBN Submarine Life Support



**Proton cell stack**



**Integrated Low Pressure Electrolyzer**

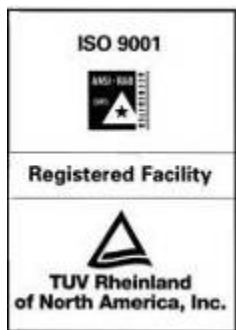
Photo courtesy of Hamilton Sundstrand



**Virginia Class  
Submarine**

# Proton Capabilities

- Electrolysis System and Cell Stack R&D
- Product Manufacturing & Testing
- World-Wide Sales & Service
- Integration of electrolyzers into complete hydrogen solutions



**CELL STACK  
MANUFACTURING**






**SYSTEMS  
MANUFACTURING**



**CELL STACK  
R&D**



# Commercial Product Details

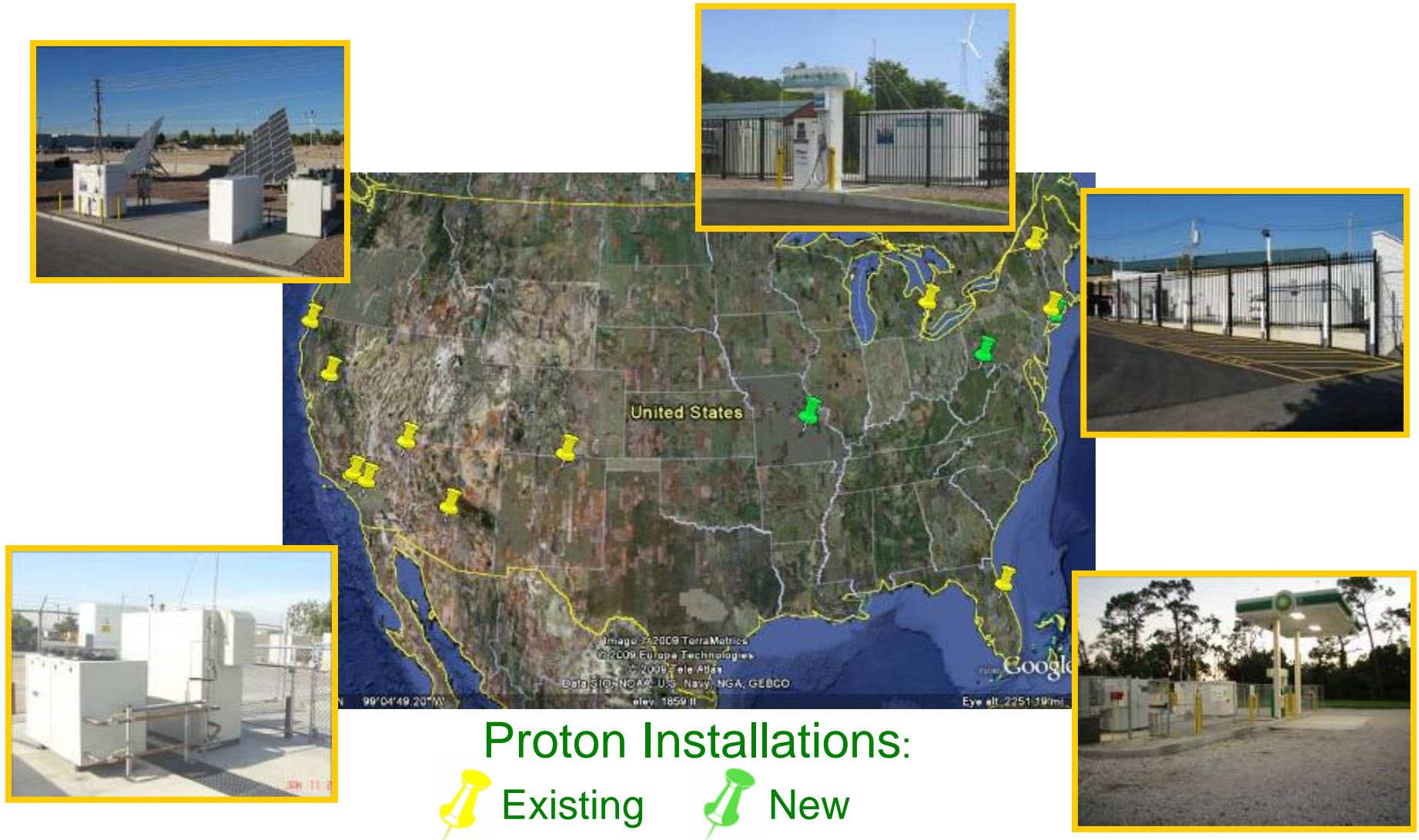
	HOGEN® GC Series	HOGEN® S-Series	HOGEN® H-Series
			
<b>Year Introduced</b>	1999	2000	2004
<b>Applications</b>	Laboratories	Industrial Gas Generation Meteorological Industries Fuelling Industries	Power Plants Heat Treating PCB Industries
<b>Generator Rate</b>	300 or 600 cc/min	0.5 to 1.0 Nm <sup>3</sup> /hr H <sub>2</sub> 1-2 kg/day	2-6 Nm <sup>3</sup> /hr H <sub>2</sub> ; 4-12 kg H <sub>2</sub> /day
<b>Hydrogen Pressure</b>	Pressure to 13 bar	15 bar	15 & 30 bar
<b>Ultra-High Pressure Hydrogen Purity</b>	99.9999+%	99.9995+%	99.9995+%
<b>Dimensions</b>	23 x 37x 52 cm	97 x 79 x 106 cm	200 x 80 x 200 cm
<b>Weight</b>	23 kg	215 kg	700-800 kg

# Hydrogen Industrial Markets

- Hydrogen is fastest growing industrial gas: 7%/year
- Major industrial gas consuming industries
  - Power plants
  - Semiconductor manufacturing
  - Flat panel computer and TV screens
  - Heat treating
  - Analytical chemistry  
(pharmaceuticals, environmental testing)
- Distributor alliances drive market acceptance



# Emerging Market: Hydrogen Fueling



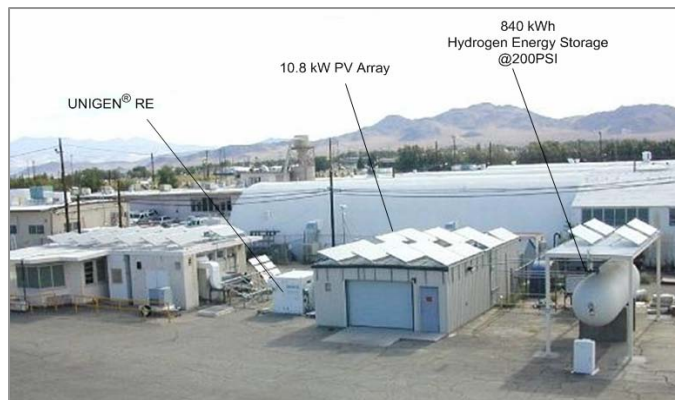
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# Emerging Market: Backup Power

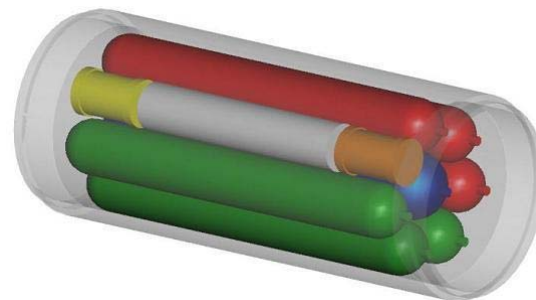
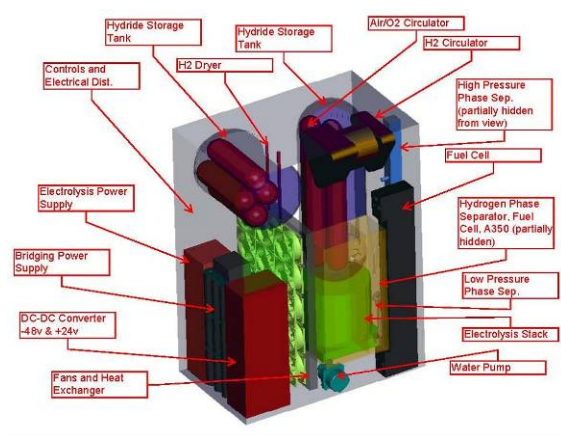
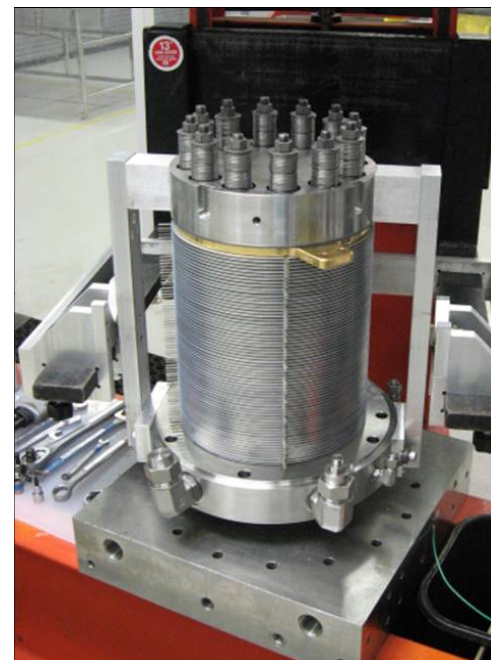


# Emerging Market: Renewable Energy Storage





# Military and Aerospace Market



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# Military and Aerospace Applications

Various military and aerospace applications are enabled by PEM electrolyzer technology:

- Unmanned underwater and aerial vehicles
- Remote camp energy storage
- Space based systems – lunar colonies and satellites
- Submarine life support
- Fueling of specialty vehicles



# 65 kg/day Fueling Platform Development Program Overview



- Prime Contractor: Select Engineering Services
- Period of Performance: Sept 2008 to Mar 2010
- Top level objective: scale up Proton's existing commercial hydrogen output by more than a factor of 5, simultaneously improving system efficiency and reducing the net cost/kg of hydrogen.

# 65 kg/day System Development (“C Series”): Work Plan Split

- TARDEC Program
  - Gas management system development and validation
  - Power supply development and prototype testing
  - Larger scale cell stack testing
- Proton IR&D
  - Controls, cell stack power supplies, AC/DC power distribution, safety system, cell stacks
  - Final integration and testing of 65 kg/day prototype

# TARDEC program leverages cell stack development program for Navy life support

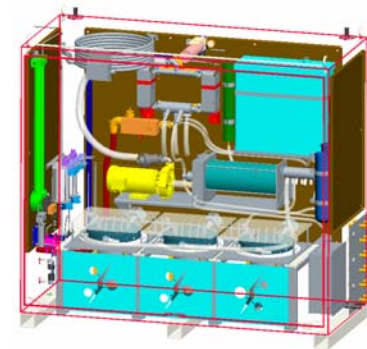
- Hamilton Sundstrand chose Proton to develop and manufacture cell stacks for its Navy customers (U.S. and U.K.)
- Proton completed design cycle in 18 months (through MIL-S-901D Shock and MIL-STD-167-1 Vibration qualification testing).
- High reliability stack platform ready for insertion into TARDEC supported BOP system.
- Enables new product launch (C-Series)



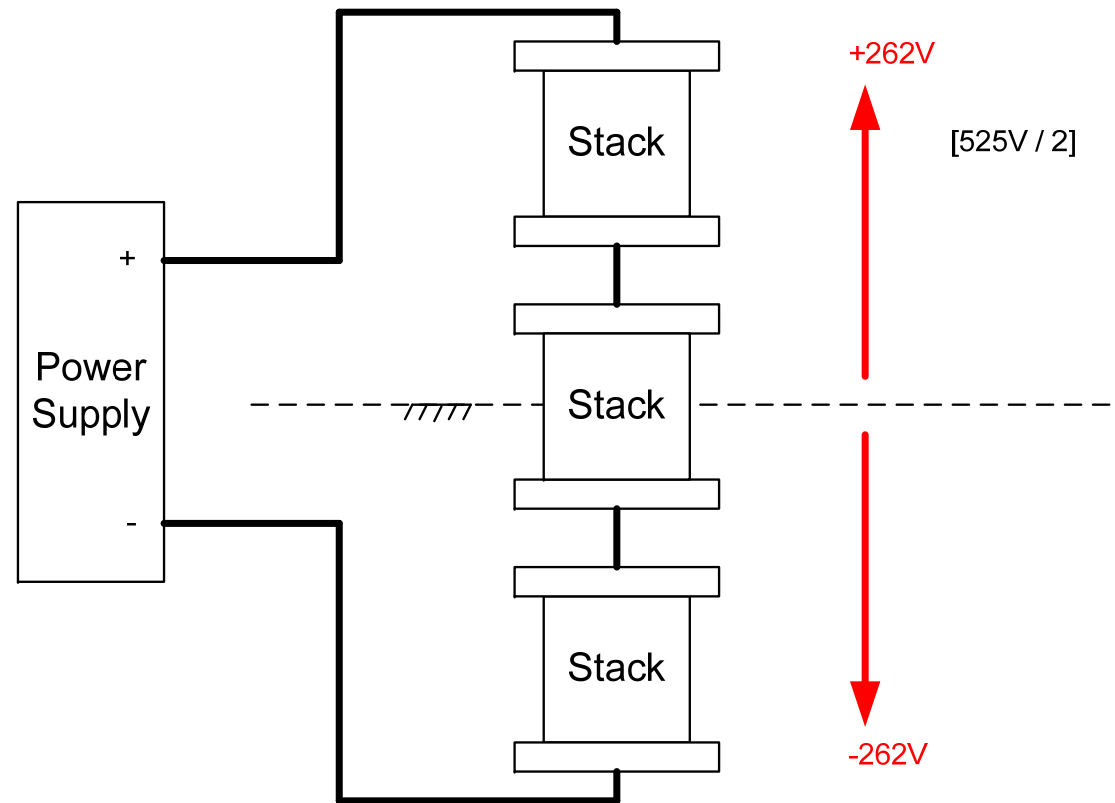
Proton PEM cell stack for UK Vanguard subs

# TARDEC Program Elements

- 1.0 Power Supply
  - Develop and test full-size P/S with efficiency target of  $\geq 94\%$ .
  - Use FuelGen12 system as long-term test bed.
- 2.0 Bi-polar Plate Cell Stack
  - Test both 15 barg and 30 barg designs.
  - Verify scale-up from 0.1ft<sup>2</sup> to 0.6ft<sup>2</sup> for 3 cells.
  - Use DOE 0.6ft<sup>2</sup> test rig for validation.
- 3.0 Gas Management System
  - GMS being designed for and tested in a complete 65 kg/day system.
  - Net reduction in dryer losses from 10% to <2%.



## 1.0 Power Supply Achievement: > 97% efficiency

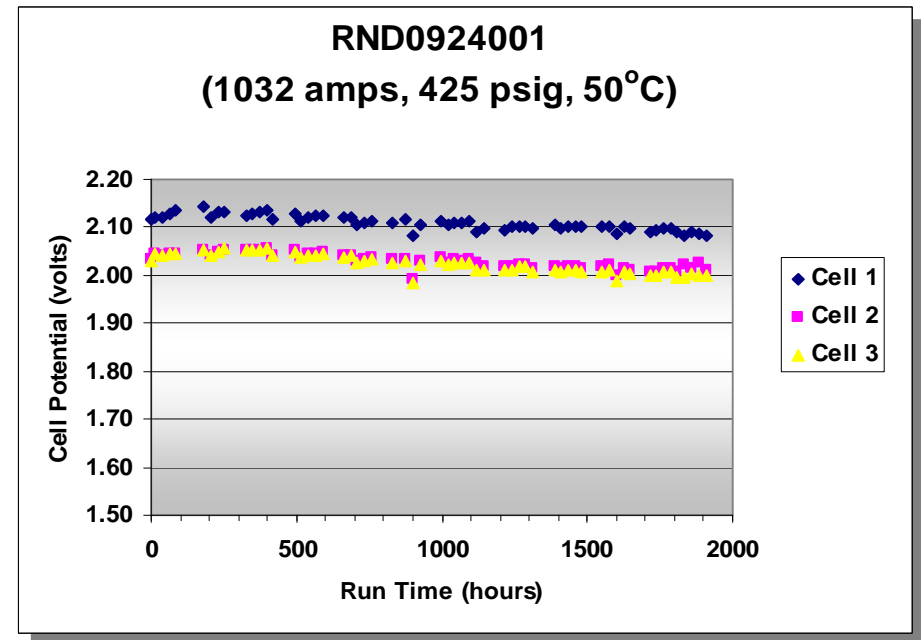


The optimum power supply design resulted in powering cell stacks in series to achieve DC voltages near same range as AC voltages(525V).



## 2.0 Cell Stack Achievements

- Completed the 0.6 ft<sup>2</sup> short stack test stand.
- Assembled, tested and operated four separate cell stacks without any failures.
- Enables further scale-up of system to beyond 130 kg/day.

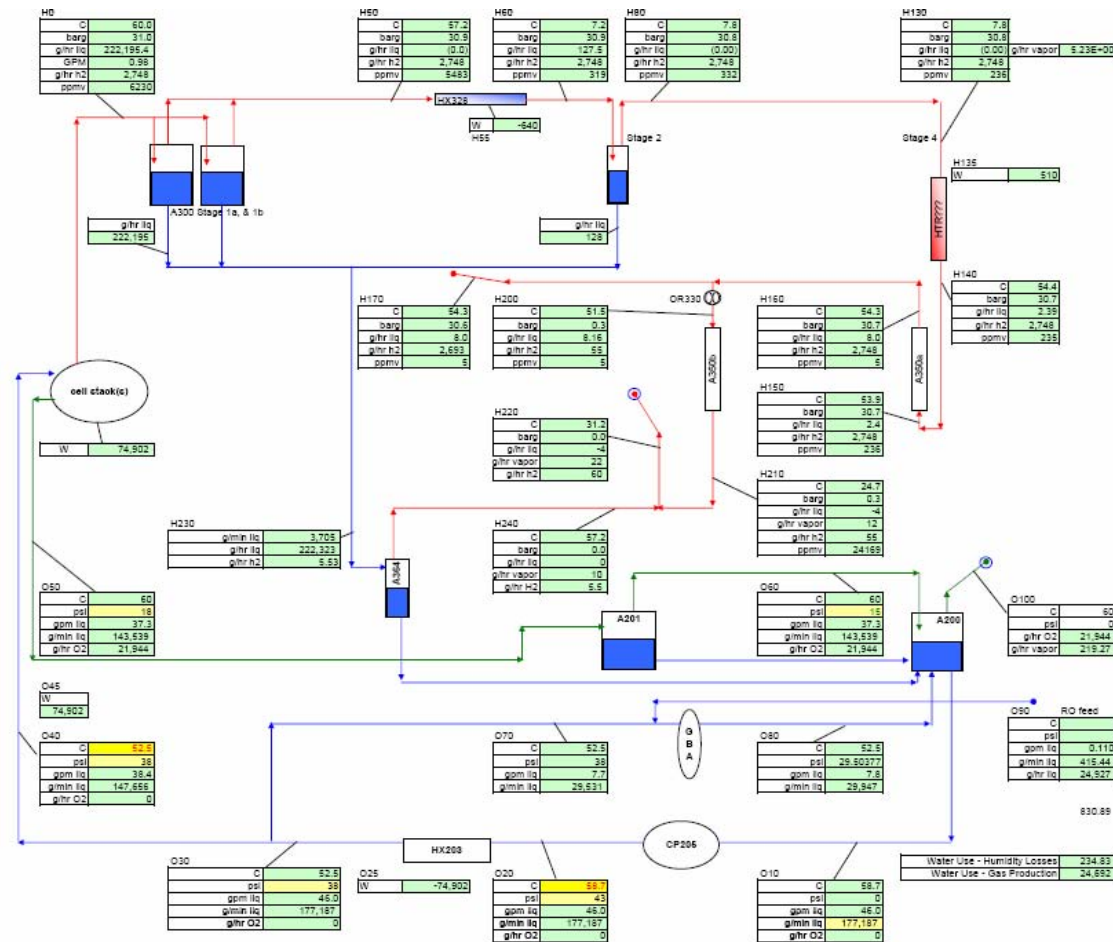


## 3.0 GMS operational test platform: functional 65 kg/day Electrolyzer

- Heavily instrumented to validate system model
- System modifiable/configurable to:
  - meet TARDEC goals
  - test component improvements
- Operating at full output (65 kg/day)
  - collecting operational data
  - verifying dryer loss target (<2%)

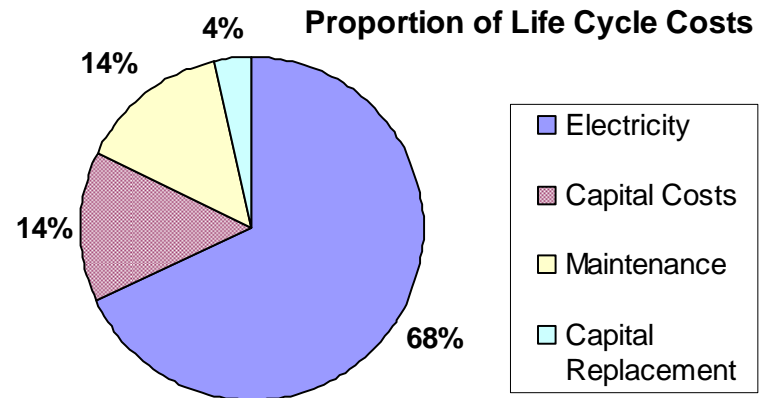


# System Model – Validated by test program!!!

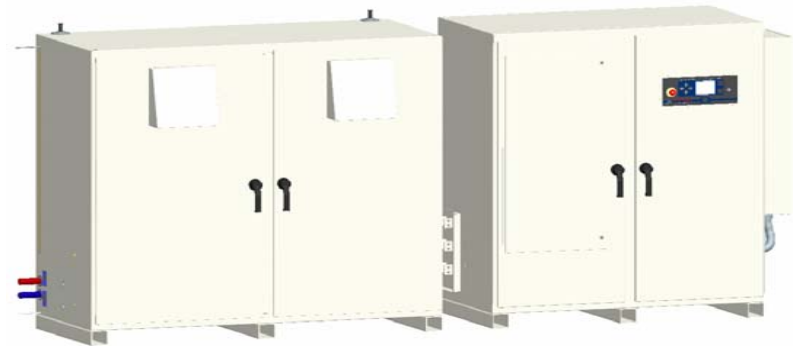


# Program Accomplishments

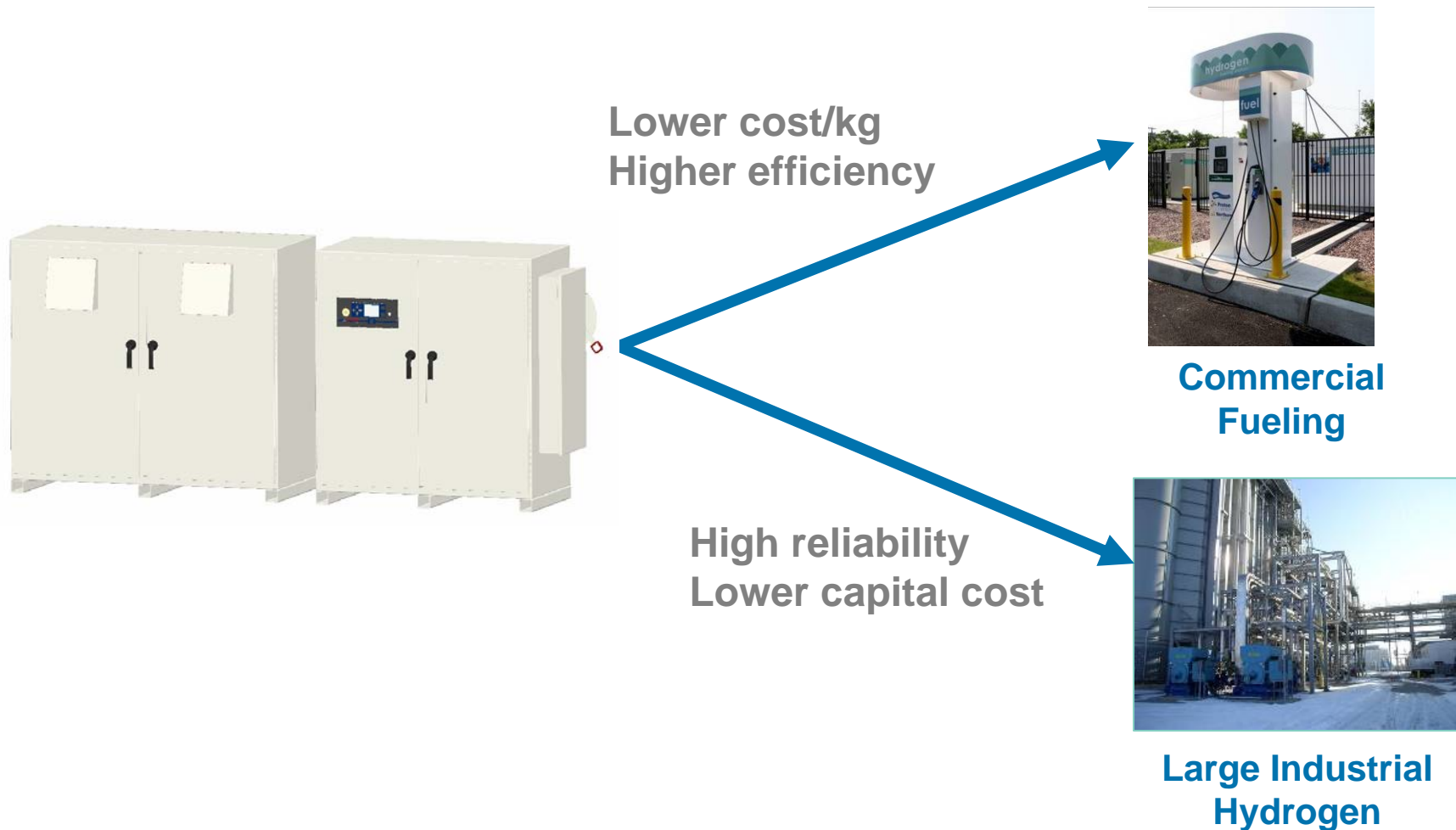
- Enables deployment of largest PEM electrolysis systems ever built.
- Accomplishes electrical efficiency improvements of nearly 14%.
- Validates projected cost targets of ~ \$5.00/kg H<sub>2</sub> for modest production volumes.
- Creates opportunities for zero emission fuel for vehicles in the TARDEC domain.
- Creates opportunities for immediate commercial sales to large industrial users of H<sub>2</sub>.



H2A cost analysis validated



# Net result is a product pathway that addresses both near term and emerging markets.



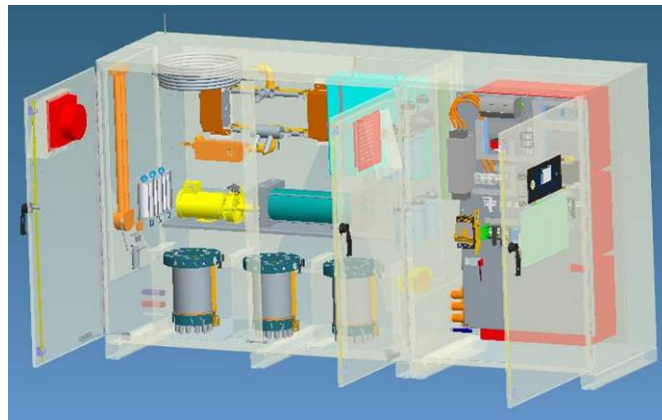
# Program Value Demonstrated

- Net result is a validated electrolyzer system that offers high efficiency, low cost production of hydrogen fuel from renewable sources.
- Dual use capability of this system (fueling and industrial hydrogen) provides an immediate commercial outlet for this new platform.
- New larger cell stack platform offers the opportunity for further cost reduction and scale-up in future development program.



# New electrolyzer platform enabled: HOGEN<sup>®</sup> C Series

- Maximum Capacity: 30 Nm<sup>3</sup>/hr H<sub>2</sub> (65 kg/day)
- Development cycle: 12 months to working prototype (12/09).
- Full Commercial availability: Q1 2011.
- 5 times the hydrogen output of the H-Series yet **only 1.5x the foot print.**
- Uses stack platform developed for Navy life support application and BOP design developed and validated under TARDEC program.
- Cooperative investment enables new product with broad application!



## Next Step: Integration into containerized fueling package and field demonstration

- Proton designing a deployable fueling station configuration packaged in 40 foot ISO containers.
- Initial prototype to be sited on Proton property in Wallingford, CT (summer 2010).
- Configured for insertion of 65 kg/day electrolyzer developed under TARDEC program.
- Dual pressure (350/700 bar) fast fill dispensing.
- Evaluating potential sites for deployment of the packaged 65 kg/day station in a demo program (available for delivery in Q4 2010).